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HUMAN RESOURCES

SIMULATION OF SYNTHETIC APERTURE RADAR I: FEATURE DENSITY AND ACCURACY REQUIREMENTS

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Three experiments were conducted to determine the minimum feature density in the Defense Mapping Agency's Digital Feature Analysis Data (DFAD) required to produce acceptable simulations of high-resolution ground maps produced by Synthetic Aperture Radar (SAR). Experienced SAR operators served as subject-matter experts in these studies. In the first study, B-1B and F-15E SAR operators were asked to rate SAR simulations produced using four data base densities. This study found that features 15m or larger needed to be portrayed individually to produce acceptable simulations for a majority of operators. A currently available DFAD product with a 30m capture criterion (Level 2) was not acceptable, whereas a higher resolution of 10m (Level X) was not found to be necessary. The second study identified Radar Scope Interpretation (RSI) cues used by 22 B-1B Offensive Systems Officers (OSOs). The RSI study found that 97% of the small features used as cues were within 1/4nm of the aim-point while lines of communication (roads, rivers) were used throughout the scene. The final study compared OSO performance on a navigation update task using SAR simulations produced from data bases with 10m and 15m capture criteria, and from existing products with 30m (Level 2) and 100m (Level 1) capture criteria enhanced with

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generic information in areas of high feature density. It was found that task performance, operator confidence, and rated acceptability for the 10m, 15m, and enhanced 30m data bases were not significantly different; the enhanced 100m data base was significantly poorer for all measures. Based on the results of these studies, it was determined that effective SAR simulations can be produced from the existing 30m DFAD product when appropriately enhanced with generic information.

SUMMARY

Simulations of ground mapping radar are generated from Defense Mapping Agency Digital Feature Analysis Data (DFAD) products which were developed to support real beam ground mapping radar. Criteria for inclusion of an object within a given level of DFAD are radar significance, height, and size. In general, Level 1 includes objects 100m and larger and Level 2 includes objects 30m and larger. A prototype DFAD incorporating features as small as 10m (Level X) was developed to support the higher resolution Synthetic Aperture Radar (SAR); however, the minimum data base requirements for simulating SAR have not been determined. The present report describes three studies conducted to determine these requirements. In the first study, B-1B and F-15E radar operators rated SAR simulations produced from Level 2 DFAD (30m) and Level X (10m), plus two experimental data bases with 15m and 20m capture criteria. Eighty-two percent of SAR-experienced subjects found the 15m data acceptable. Simulations produced from Level 2 depicted areas of high reflector density as a single feature with uniform brightness and were acceptable to only 18% of the subjects. A study of the Radar Scope Interpretation (RSI) cues used by B-1B Offensive Systems Officers (OSOs) found that roads and rivers were critical cues, whereas individual structures were used only in the immediate vicinity of the aimpoint. Based on these findings, it was predicted that areas of high feature density could be depicted generically without affecting task performance. A third study compared B-1B OSO performance on a navigation update task using 10m and 15m feature data and generically enhanced 30m (Level 2) and 100m (Level 1) data. This study found that task performance, operator confidence, and rated acceptability using 10m, 15m, or enhanced 30m data were not significantly different. The authors concluded that the density of task-critical features in Level 2 DFAD is sufficient to simulate SAR but that high density areas must be enhanced to create acceptable simulation fidelity.

PREFACE

This project was conducted in support of the Air Force Human Resources Laboratory's Technical Planning Objective: Aircrew Training Technology. The goal of this effort is to develop cost-effective strategies and equipment for aircrew training. The research was conducted under Work Unit 1123-33-01, Fidelity Requirements for Sensor Imagery.

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The authors also express their appreciation to the Radar-Navigators, Weapons System Officers, and Offensive Systems Officers who assisted in these studies.

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I. INTRODUCTION

Digital Radar Landmass Simulators (DRLMS) generate simulated radar ground maps based on a digital model of the earth's surface. This model is often created using the Defense Mapping Agency (DMA) Digital Landmass System (DLMS) data. DLMS data consist of two files for a given area: Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data (DFAD). Measurements of terrain height above sea level are spaced at regular intervals, typically 300nm, and describe surface contours only. DFAD consist of descriptions of objects on the surface such as vegetation, cultivated fields, bodies of water, roads, cities, and structures. DMA produces these data files at differing levels of detail for different applications. Level 1 DFAD cover large expanses of the earth's surface, with relatively large minimum size requirements for portrayal of planimetric features (DMA 1983, p. 1). Level 2 DFAD cover small areas of interest and have smaller minimum size requirements for portrayal of planimetric features (DMA 1983, p. 1).

These products were developed in the 1970s to support simulations of existing real beam ground mapping radars such as the B-52, KC-135, and C-130 aircraft. These radars produce ground maps of relatively large areas and cannot resolve small features individually. Newer radars such as the Synthetic Aperture Radars (SARs) in the B-1B and F-15E, however, produce ground maps of areas as small as 4000' x 4000' with a resolution of 10' or less. Current DFAD products do not contain sufficient object density to support realistic simulations of these SARs.

Reducing the minimum size required for inclusion within the DFAD file would increase the number of features within the data base but would also increase DFAD production costs. This report describes three studies evaluating the data density requirement for simulating SAR. The objectives were: (a) to determine the minimum density of ground truth[1] data required to adequately simulate SAR, (b) to identify the critical ground features used in SAR image interpretation, and (c) to investigate the utility of selectively replacing ground truth information with synthetic imagery[2] in order to reduce cost without affecting training utility.

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[1]Ground truth denotes that each object in the data base accurately reflects an object on the ground in terms of position, size, height, orientation, feature type, and surface material.

[2]Synthetic imagery denotes that objects in the data base may not necessarily represent specific objects on the ground; features such as houses, warehouses, or secondary roads may be inserted into the data base in areas where these features are located without regard for matching specific objects on the ground.

Background

In the late 1970s the Air Force and DMA realized that current DLMS products could not support SAR simulations. In response, DMA created a prototype high-resolution DFAD called Level X. The capture criterion (i.e., the smallest horizontal dimension for individual feature portrayal) for Level X was 10m. This criterion was selected on the basis of an engineering assessment of SAR capabilities and lessons learned from simulating real beam radar. In general, features smaller or closer together than the nominal capture criterion will not be individually portrayed in the DFAD file. Radar significant features which are smaller than the criterion, however, are individually portrayed on an exception basis.

Figures 1 through 3 are DFAD manuscripts of Greybull, Wyoming at Levels 1, 2, and X. The capture criterion is 100m for Level 1, 30m for Level 2, and 10m for Level X. Level 1 contains 59 features while Level 2 contains 281 and Level X contains 1,389. Figure 4 contains an aerial photograph of Greybull for comparison.

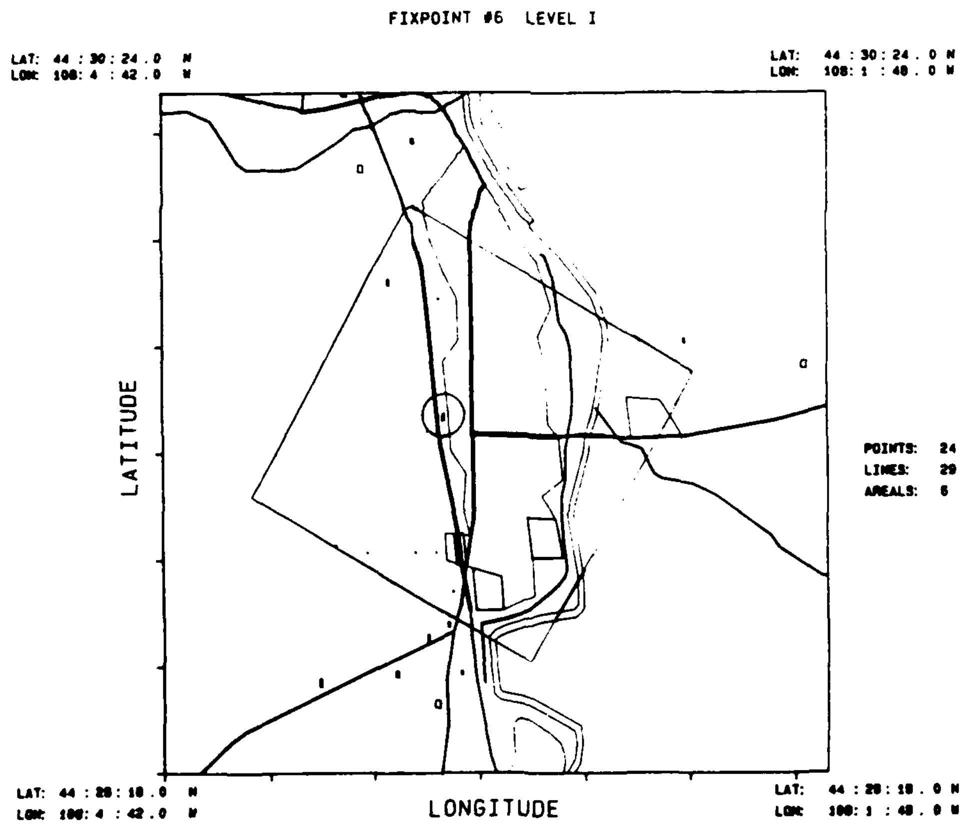

Figure 1. Plot of Digital Feature Analysis Data for Greybull, Wyoming at Level 1.

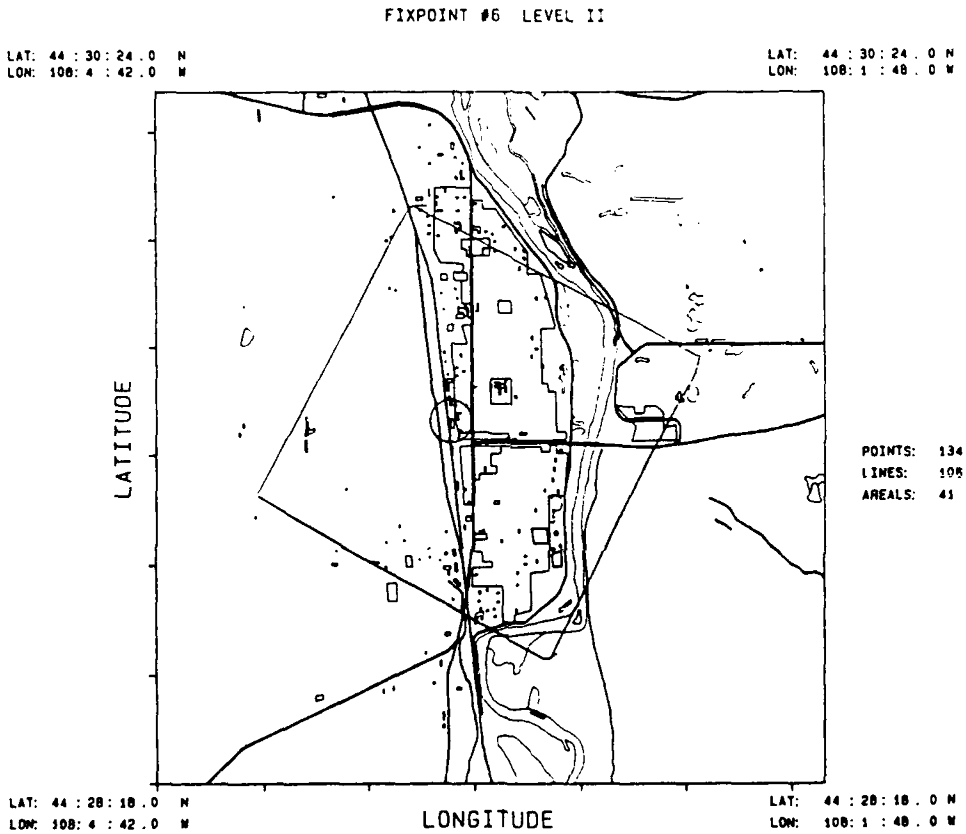

Figure 2. Plot of Digital Feature Analysis Data for Greybull, Wyoming, at Level 2.

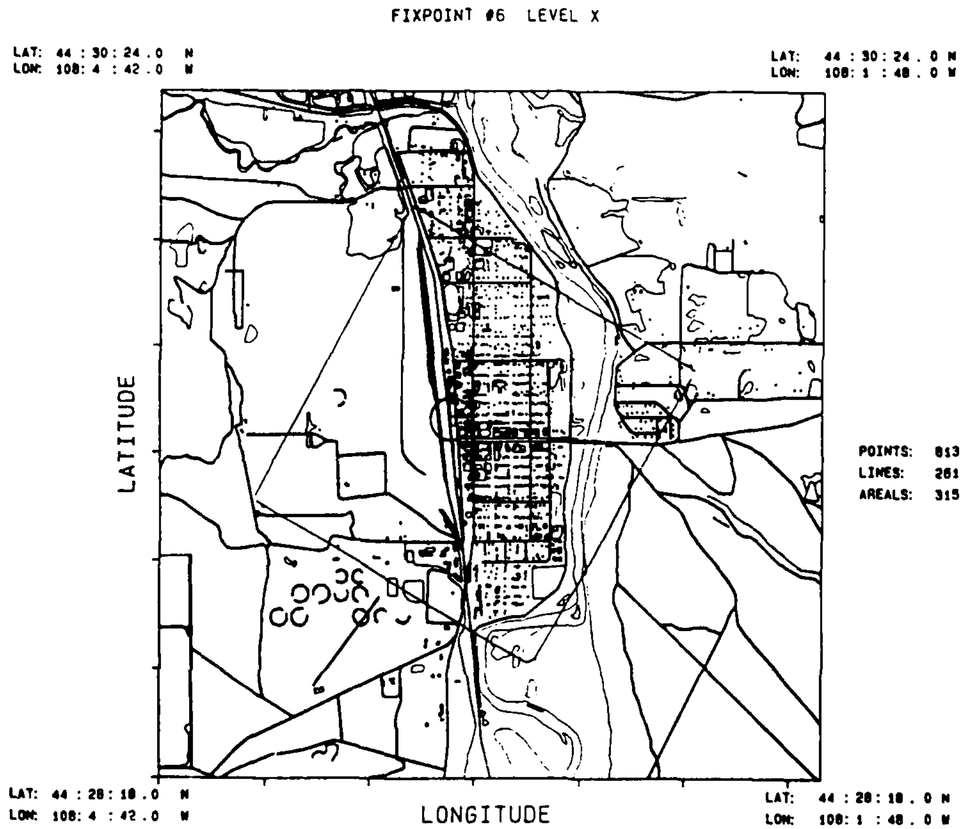

Figure 3. Plot of Digital Feature Analysis Data for Greybull, Wyoming, at Level [illegible]

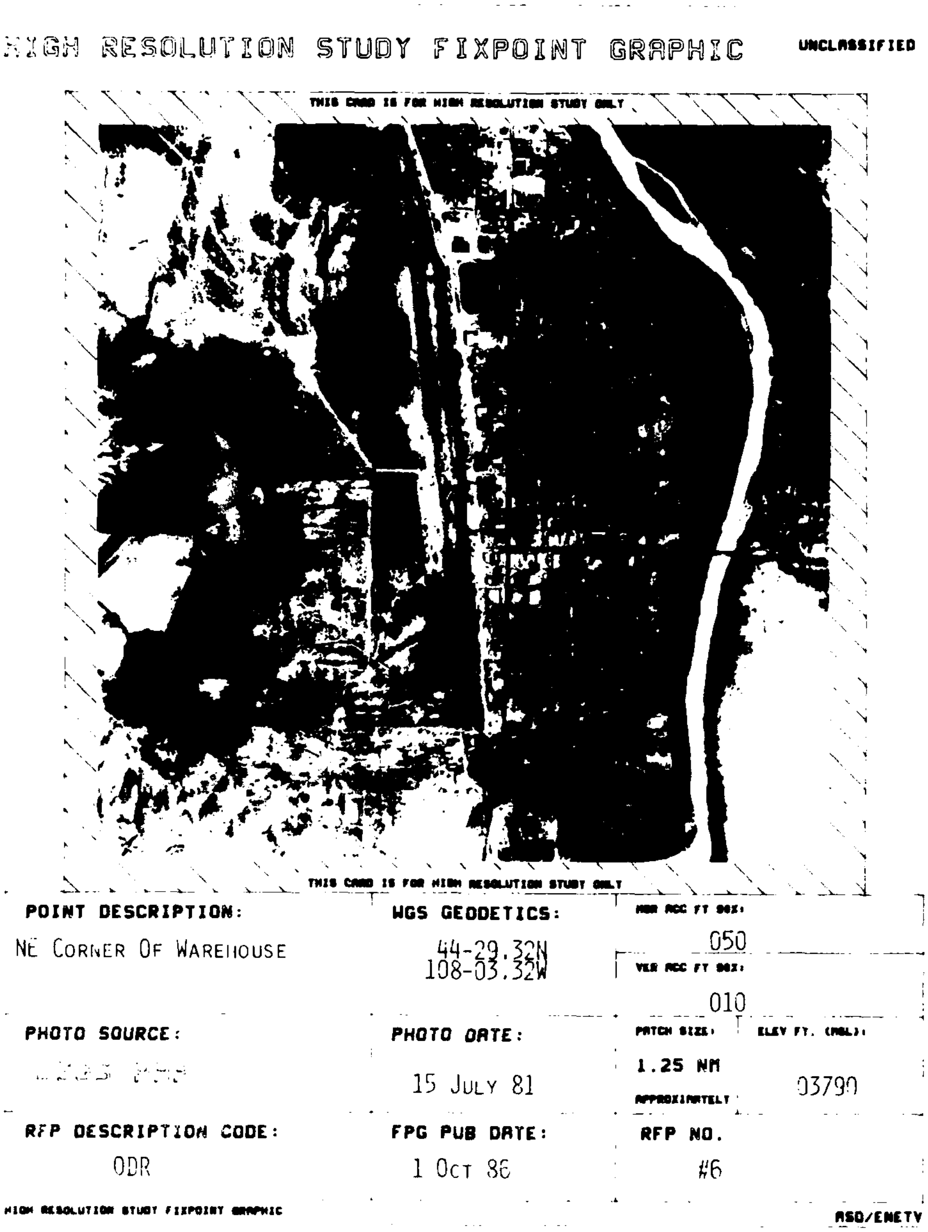

Figure 4. Fixpoint Graphic Card for Greybull, Wyoming, Including a 1.25 x 1.25 nm aerial photograph.

An engineering analysis of SAR simulations produced from Level X was conducted by The Analytical Sciences Corporation (TASC) in 1985. This analysis concluded that Level X, with minor modifications such as the addition of roof clutter on large buildings and the elimination of individual trees, would support acceptable SAR simulations. The TASC analysis did not address the issue of whether a data base less dense than Level X would adequately simulate SAR, nor were subject-matter experts (SMEs) from the using commands consulted. In 1985, the Operations Training Division of the Air Force Human Resources Laboratory (AFHRL/OT) and the Aeronautical Systems Division (ASD/ENETV) began work to determine the minimum data base density required for simulating current-generation SAR.

Overview

The three studies described in the present report were designed to do what the earlier analysis did not; namely, to consult SAR operators and instructors in order to determine the minimum data set required to adequately simulate SAR. The three studies consisted of: (a) subject-matter expert evaluations of simulated SAR generated from different data bases, (b) analysis of Radar Scope Interpretation (RSI) cues used by SAR operators, and (c) SAR operator task performance using SAR simulations generated from different data bases.

The first study examined density requirements by having both SAR-experienced and non-SAR-experienced radar operators evaluate SAR simulations produced at four levels of data base density. The evaluation consisted of having the radar operators examine photographs of the simulations and rate the acceptability of each level in terms of providing the minimum amount of detail necessary for adequate simulation. The images were created directly from the different data bases without enhancements or modifications. This study suggested that something less than Level X might be adequate for SAR simulation.

The second study was an analysis of the types of ground features used by SAR operators as RSI cues. Aerial photographs of 115 scenes were inspected by B-1B Offensive Systems Officers (OSOs). The OSOs indicated which ground features they would use as RSI cues, or pointers, in order to locate a specified aimpoint. Analysis of these data indicated that roads, rivers, and railroad tracks were critical and that many small features might be depicted generically without affecting operator performance.

The third study was an assessment of B-1B OSO task performance using simulated SAR images produced from differing levels of data base density. These included Level X which contains a very high density of ground truth information and a version of Level 2 which was enhanced using synthetic imagery to generically depict areas of high feature density. Since the RSI cue analysis indicated that individual features within dense areas were not used as pointers, it was predicted that these areas did not require detailed ground truth to support task performance. Results of this study showed that OSO task performance using the enhanced Level 2 was not significantly different from that for Level X.

These three studies demonstrated that (a) the aimpoint plus task-critical RSI cues such as roads and rivers must be accurately portrayed in order for SAR operators to perform the required tasks, and (b) the entire simulated scene must be similar to an actual SAR scene or it will not be accepted by the operators. The studies also showed that some small features can be depicted generically without reducing training effectiveness.

II. DENSITY REQUIREMENTS STUDY

Research Methods

Materials

Simulated SAR images were created from DFAD files containing different individual feature densities. These data bases were Level 2 and Level X DFAD with capture criteria of 30m and 10m, respectively, and two experimental data bases called Level Y and Level Z with capture criteria of 15m and 20m, respectively. To be individually depicted in the data base, features must have at least one horizontal dimension greater than the capture criterion. Collections of structures such as houses which are smaller and more closely spaced than the capture criterion for a given data base level were included as a single areal feature[3] which incorporated the outline of the area.

Level X DFAD were provided by DMA for four locations: Scott AFB and three fixpoints in the Strategic Training Range Complex (STRC). The Level Y and Level Z data bases were created by manually filtering the Level X data to 15m and 20m capture criteria. Level 2 DFAD were also provided by DMA for Scott AFB. Since Level 2 data were not available for the STRC locations, these data were produced by manually filtering the Level X data to conform to the Level 2 (2nd edition) DLMS specification.

SAR simulations were produced from these 16 data bases (4 densities at 4 locations) using a Singer-Link research and development SAR simulator. Simulations were produced for each location and data base density with a 1.2nm x 1.2nm patch (20' resolution) and a .67nm x .67nm patch (10' resolution). These patch sizes and resolutions are comparable to B-1B and F-15E SAR capabilities. The radar effects included in the simulations were shadow, noise, leading edge brightening, and star effects. Texture patterns were overlaid on only ground, grass, and tree areas. Terrain relief, far shore brightening, and wind effects were not simulated. Areal features containing numerous small reflectors were not enhanced. Images for the three STRC points were produced from a simulated range of 8nm and altitude 850' above ground level (AGL), producing a 1-degree grazing angle. For Scott AFB, altitude was 1,700' AGL, producing a 2-degree grazing angle.

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[3] An areal feature is any topographic feature such as sand, swamp, residential, or industrial which extends over an area. In digital mapping, an areal feature is enclosed by a delimiting line, and is assigned a single unique character (e.g., residential).

Each image was photographed and printed in black-and-white; the radar image was approximately 5.5" x 5.5" on a black background. Image resolution was 400 x 400 pixels. Features within the four scenes were: (a) Scott AFB--runways, hangars, shops, and residential housing; (b) STRC Point 29--a low cultural detail area including a river, a freeway, and some fence lines; (c) STRC point 4--a small town with a freeway on an embankment, and a power line; and (d) STRC Point 13--an isolated farm consisting of several buildings and some fences. These four sets of images were labeled, respectively: (a) Scott AFB, (b) River, (c) Town, and (d) Farm. Figures 5 through 8 show the 20' resolution SAR simulations for Scott AFB at each data base level.

Figure 5. Simulated SAR Image of Scott AFB Used in the Density Requirements Study Generated from level 2 (30nm) Data. Only the soil and tree areas have been textured; no enhancements have been added to other features. Patch size is 1.25 x 1.25nm; simulated radar resolution is 20'.

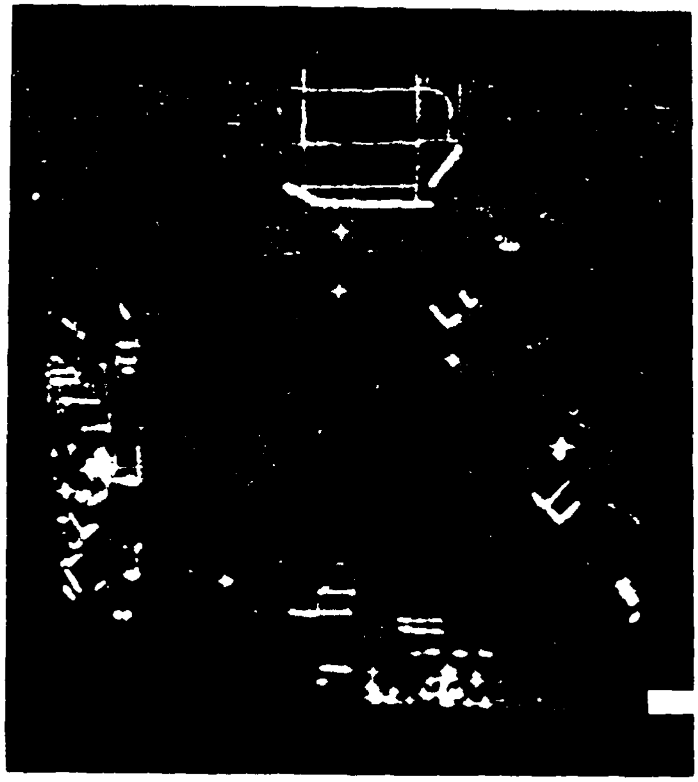

Figure 6. Simulated SAR Image of Scott AFB Used in the Density Requirements Study generated from Level Z (20m) Data.

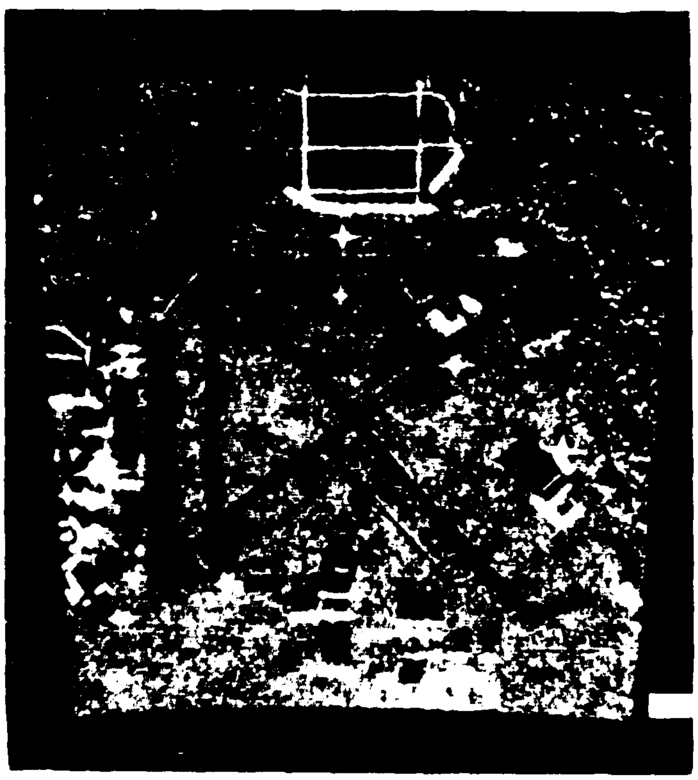

Figure 7. Simulated SAR Image of Scott AFB Used in the Density Requirements Study Generated from Level Y (15m) Data.

Figure 8. Simulated SAR Image of Scott AFB Used in the Density Requirements Study Generated from Level X (10m) Data.

Subjects

Data were collected from two groups of radar operators. The non-SAR-experienced consisted of 30 B-52 Instructor Radar-Navigators whose experience was limited to real beam ground mapping radars. The SAR-experienced group of subjects included 14 B-1B OSOs and 3 F-15E Weapons Systems Officers.

Procedure

Subjects participated individually or in groups on an as-available basis within their squadrons. The purpose of the study was explained and the characteristics of the test images described. For each of the four fixpoints, subjects examined the 10' and 20' resolution images and rated the acceptability of each data base level. It was pointed out that where absolute ground truth was not required, synthetic imagery corresponding to the general characteristics of an area (such as residential housing) could be added to the images. This type of enhancement would be generically correct but not specific to a given area. The images were spread out on a table top; subjects examined and compared them without time constraints and rated on questionnaires whether each image contained the "minimum acceptable ground truth information necessary for simulating SAR for any purpose, including training, mission planning, and mission rehearsal." The exact aimpoint within each scene was not specified nor were aerial photographs or charts provided. Subjects were encouraged to offer comments or suggestions about the images or about the test procedures.

Results and Discussion

Table 1 and Table 2 show the number of subjects rating a given level of detail as "minimally acceptable" for the non-SAR-experienced and SAR-experienced groups, respectively. A log-linear analysis comparing the marginal totals for the SAR-experienced and the non-SAR-experienced groups shows that the two groups rated the images differently ($X^2(17)=30.0$, $p<.05$). The two groups will therefore be discussed separately.

Table 1. Minimum Acceptable Data Base Level Rated 30 Non-SAR-Experienced Radar Operators

	Level			
	X (10m)	Y (15m)	Z (20m)	2 (30m)
Scott AFB	3	4	15	8
River	2	26	2	0
Town	1	4	19	6
Farm	1	9	14	6
Total	7 (6%)	43 (36%)	50 (42%)	20 (16%)

Examination of the data from the non-SAR-experienced group, Table 1, shows that for the River fixpoint 2 (6.6%) of the subjects rated Level X as minimally acceptable, 2 (6.6%) rated Level Z as minimally acceptable, and 26 of the 30 (86.6%) rated Level Y as minimally acceptable. The pattern of responses for the other three fixpoints is markedly different from that of the River fixpoint.

Table 2. Minimum Acceptable Data Base Level Rated by 17 SAR-Experienced Radar Operators

	Level			
	X (10m)	Y (15m)	Z (20m)	2 (30m)
Scott AFB	4	5	7	1
River	2	14	1	0
Town	0	7	7	3
Farm	5	7	4	1
Total	11 (16%)	33 (49%)	19 (28%)	5 (7%)

Inspection of the data from the 17 SAR-experienced subjects, Table 2, reveals that for the River fixpoint, 2 (12%) rated Level X as minimally acceptable, 14 (82%) chose Level Y, and 1 (6%) chose Level Z. The pattern of responses for the other three fixpoints is different than that for River.

The River fixpoint image includes very little cultural detail; there are a river, a freeway, and some fence lines. When the data base was filtered from Level X to Level Z, the river itself was changed from an areal feature to a narrow line feature which does not appear on the photographs for Level Z or Level 2. The river therefore disappears between Level Y and Level Z, leaving very few features in these images. Subjects' comments were consistently critical of the absence of the river in the less detailed images since rivers are often used as RSI cues or aimpoints. As a result, subjects required that the river be present in the images and, since little detail was added in Level X over Level Y, 85% of all subjects rated Level Y as containing the minimally acceptable level of detail. Since the results for the River fixpoint were driven by the presence or absence of a single feature and not the overall level of detail, the data for this set of images were considered aberrant and omitted from further analyses. Marginal totals for Scott AFB, Town, and Farm are presented in Table 3.

Table 3. Minimum Acceptable Data Base Level for SAR-Experienced and Non-SAR-Experienced Subjects for Scott AFB, Town, and Farm

	Level			
	X (10m)	Y (15m)	Z (20m)	2 (30m)
non-SAR-experienced	5 (6%)	17 (19%)	48 (53%)	20 (22%)
SAR-experienced	9 (18%)	19 (37%)	18 (35%)	5 (10%)

Since the feature density decreased from Level X to Level 2, a subject selecting a given data base level as minimally acceptable would rate more dense levels as also acceptable. Among the non-SAR-experienced subjects, 22% found Level 2 acceptable. When the density was increased to Level Z, an additional 53% or a total of 75% of the subjects rated Level Z as acceptable. However, among the SAR-experienced subjects, only 10% found Level 2 acceptable and increasing density to Level Z added only 35%, for a total of 45%. That is, less than half of the SAR-experienced operators were satisfied with Level Z. Increasing the density to Level Y adds 37%, for a total of 82%. It can be seen, therefore, that demand for detail in radar simulations increases with experience in using high-resolution radar. It can also be seen that a data base density greater than Level Z (20m) is required in order to satisfy at least half of the SAR-experienced operators.

In addition to the ratings, subjects were asked to offer comments about the simulations and the task. The comments indicated that the task of selecting the "minimum acceptable density" was somewhat ambiguous because the aimpoint was not specified. For example, if a B-1 OSO were asked to center-aim a cluster of returns, then returns from small features would not be required. Alternatively, returns from small features would be required if the specified aimpoint were an isolated reflector or an individual reflector within a cluster of objects. The variable responses for Scott AFB, Town, and Farm reflect differences of opinion as to what the appropriate aimpoints should be. Subjects who rated Level X as minimally acceptable for Scott AFB or Farm commented that they would choose very small aimpoints such as the corner of a building or an intersection of two fences; subjects who would choose larger targets such as the intersection of runways or who would center-aim the cluster of buildings in Farm specified less detail as minimally acceptable. Overall, the rated level of acceptability depended on both the size and density of features. High density data bases were required when small features would be individually detected in a SAR image; however, they were not required when the features were so close together that no single object would be picked as an aimpoint. Larger landmarks within a densely packed area, such as the lines of communication in the housing area at Scott AFB (see Figures 5 and 6), were demanded regardless of feature size. Finally, several SAR-experienced subjects commented that as they gained experience in using SAR in their aircraft they were looking for smaller and smaller aimpoints which were typically isolated reflectors such as fence intersections and microwave towers.

Several suggestions were offered regarding future studies. In addition to specification of aimpoints, subjects wanted more information about what features were really on the ground and what they would look like on SAR. For each fixpoint, subjects would like to see an actual SAR image or a vertical photograph of the ground patch being simulated.

The following conclusions are supported by the data collected in this study:

1. With experience, operators tend to select smaller objects and features as aimpoints. These features tend to be isolated reflectors or small parts of larger structures. When operators choose small objects as aimpoints, their demand for detail in DFAD increases.

2. Overall, the SAR-experienced subjects found Level 2 unacceptable; rated Levels Y (15m) and Z (20m) as acceptable equally often; but preferred Level X, where a small object could be used as an aimpoint. At a minimum, therefore, DFAD data must contain a feature density somewhere between Level Z (20m) and Level Y (15m) to adequately simulate SAR for a majority of experienced users.

III. SAR RADAR SCOPE INTERPRETATION CUE ANALYSIS

Introduction

Radar Scope Interpretation (RSI) cues or pointers are surface features that serve as reflectors to aid radar operators in locating an aimpoint. These pointers are identified from charts and photographs of the target area during pre-mission study. Typically, the operator will select distinctive features to provide overall orientation and then locate successively smaller features to help locate the target. For example, in Figure 4, Greybull, Wyoming, the circled building at the center of the photo is the target. The operator would first look for the river on the east edge of town and the railroad tracks on the west. The operator would then look for the bridge and main road running east to west. The target is therefore the first major reflector north of the main road where it intersects the railroad tracks.

The results of the Density Requirements study indicated that not all features within a scene are of equal importance for SAR operators. The major difference between Level X (10m) and Level Y (15m) is that features the size of houses within residential areas are individualy portrayed in Level X and aggregrated into a single areal feature in Level Y. This aggregation is illustrated by the housing area at the north edge of Scott AFB in Figures 7 and 8. Over 70% of the SAR operators in the Density Requirements Study found Level Y acceptable, indicating that they did not require depiction of structures such as houses but that the roads within the housing area were necessary.

This RSI Cue Analysis study was conducted to more systematically determine what surface features SAR operators use as pointers. The objective of the study was to identify the characteristics and locations of pointers relative to the aimpoint for different types of scenes. These data could then be used to specify what features require ground truth depiction within a simulated SAR image and what features could be depicted generically without affecting operator performance.

Research Methods

Overview

For their pre-mission study, B-1 OSOs examine Fixpoint Graphic cards similar to Figure 4. The card contains the geodetic coordinates and elevation of the specified fixpoint and a 1.25nm x 1.25nm vertical photograph of the area surrounding the fixpoint. The OSO identifies RSI cues in the photograph so that he can quickly locate the target on the radar scope. For the RSI Cue Analysis, OSOs were asked to examine a number of Fixpoint Graphics and to indicate the RSI cues they would use. These data were then analyzed to determine the type, size, and location of SAR pointers for several types of scenes.

Materials

Unclassified B-1B Fixpoint Graphics were obtained for 115 targets in the Strategic Training Range Complex. The 115 scenes were assigned to one of four categories, depending on the feature specified as the fixpoint and the surrounding features. The categories were: Urban, Small Group, Isolated, and Terrain. The Fixpoint Graphics were then divided into five sets of 23 with approximately equal numbers of Urban, Small Group, Isolated, and Terrain scenes in each group.

Subjects

Twenty-two SAR-experienced B1-B OSOs from the 96th BMW, Dyess AFB, Texas served as subject-matter experts. Mean flight time in the B-1 for these OSOs was 110 hours.

Procedure

OSOs were contacted at their squadrons. Each OSO performed an RSI Cue analysis on one of the five sets of fixpoint graphics..The analysis consisted of first examining the Fixpoint Graphic and then marking a photocopy of the graphic with a highlighter to indicate the SAR-relevant pointers. The task was self-paced and took between 10 and 20 minutes.

Results and Discussion

Each highlighted feature was assigned to one of four pointer classifications: Lines of Communication (LOCs)--roads, railroad tracks, power lines; Natural Features/Vegetation--rivers, lakes, treelines, plowed fields; Structures--man-made objects occupying three-dimensional space; and Terrain--elevation and shadow effects. The percentages of pointer types selected for each scene type are listed in Table 4.

Table 4. Classification of Pointer Types and Scene Types

	Scene Type				
Pointer Type	Urban	Small Group	Isolated	Terrain	Total
LOCs	69%	60%	57%	10%	56%
Natural Features	13%	19%	27%	8%	20%
Structures	17%	20%	12%	1%	15%
Terrain	1%	1%	4%	81%	9%

Examination of Table 4 shows that the majority of features used as RSI cues for scene types other than terrain were Lines of Communication. Terrain was used as a pointer only where the aimpoint itself was a terrain feature. In scenes where there were no visible LOCs, 99% of the highlighted RSI cues were Terrain features. For scenes in which roads or railroad tracks were present, 60% of pointers highlighted were LOCs (i.e., lineal features that typically extend across much of the scene). Road intersections and grade crossings were not scored as separate features; however, the comments of the OSOs as they were highlighting pointers indicated that a typical approach would be to find the major LOCs and then follow them to an intersection. The aimpoint would then be located relative to this intersection. RSI cues for Greybull, Wyoming (Figure 4) cited earlier would be a typical example.

After LOCs, Structures were cited most frequently for Urban and Small Group scenes whereas Natural Features/Vegetation was the next most common pointer for Isolated scenes. The types of structures highlighted were most often the largest or tallest structure within an area, such as a grain elevator or a tower. Since Isolated scenes were defined by the absence of other man-made features, it is not unexpected that Natural Features are commonly cited pointers. Like the LOCs, these Natural Features tended to be large and extend across a significant portion of the scene.

One option in developing a high-resolution data base would be to include only a small high-resolution patch around the aimpoint. Analyses were conducted to determine if the highlighted types of pointer (e.g., Structures vs. LOCs) varied as a function of distance from the aimpoint. For features such as roads or rivers, distance was computed from the aimpoint to a location halfway between the nearest and most distant points on the feature. For the photographs on the Fixpoint Graphics which covered a 1.25nm x 1.25nm patch, the radial distance from the aimpoint to the closest edge is 0.625nm or 3,800'. Distances from pointers to the aimpoints were classified into four zones: 0nm (i.e., the pointer is the aimpoint), less than 0.125nm (760'), less than 0.25nm (1,520'), and less than 0.5nm (3,040'). These data are summarized in Table 5.

Table 5. Classification of pointer type and distance from the aimpoint. Distance zones are cumulative so that 100% of highlighted RSI cues are within 0.625nm of the aimpoint.

	Distance Zone			
Pointer Type	0nm (pointer is aimpoint)	<0.125nm (760')	< 0.25nm (1,520')	< 0.5nm (3,040')
LOCs	10%	65%	86%	99%
Natural Features	14%	53%	84%	99%
Structures	65%	92%	97%	100%
Terrain	18%	53%	75%	98%
Total	20%	65%	86%	99%

The data in Table 5 show that the types of SAR features used as pointers change as a function of distance from the aimpoint: 92% of Structures which were highlighted as significant RSI cues were less than 760' from the aimpoint. In the majority of these cases, the Structure was the aimpoint. Many OSOs stated that if the aimpoint was an isolated Structure (such as a radio tower) or was the tallest Structure in an area (such as a grain elevator), the Structure would be the brightest reflector in the scene and serve as an RSI cue. Individual Structures were therefore rarely used as pointers unless they were in the immediate vicinity of the aimpoint.

LOCs and Natural Features, however, were used as pointers throughout the scene. Further analysis of the RSI data shows that the area containing 75% of the highlighted LOCs extended from the aimpoint to 1,155' while 75% of the Natural Features were within 1,340'; 75% of the highlighted Terrain features extended to 1,520'.

This analysis of RSI cues suggests that the amount of ground truth feature density provided by Level X and Level Y may not be required for the entire scene. The smallest features highlighted as pointers were Structures, and the great majority of these were within the immediate vicinity of the aimpoint. In addition, the highlighted Structures were most often relatively large buildings such as grain elevators. Individual structures outside this area might be depicted generically by breaking up areal features such as the housing area at Scott AFB (Figure 5). Conversely, LOCs and Natural Features such as roads, railroad tracks, rivers, bodies of water, and areas of uniform vegetation need to be portrayed accurately throughout the scene. A simulated SAR image containing both ground truth and generic features would be less accurate than Level X but the loss in accuracy might not affect operator performance because the generic features would not be task-critical. The simulation would also look sufficiently like SAR to ensure operator acceptance.

IV. HIGH-RESOLUTION OPTIMIZATION STUDY

Introduction

The major conclusion drawn from the Density Requirements study was that data base density greater than current DMA DFAD products was required to support SAR simulation. The RSI Cue Analysis, however, suggested that the features contained in Level 2 (e.g., large Structures and LOCs) were of major importance in executing SAR tasks. Features unique to Level Y or Level X, such as smaller Structures, were infrequently cited as pointers. On the basis of these findings, it was predicted that Level 2 data might be enhanced in ways that would maintain SAR-like appearance of the simulation and still support B-1B OSO task performance. In particular, the large block areal features in Level 2 which represent aggregations of smaller reflectors could be broken up generically to resemble the appropriate ground returns but without maintaining strict ground truth. Major LOCs, however, would have to retain ground truth even within enhanced areas.

To test this prediction, a simulator-based study was designed using both task performance and subject-matter expert ratings as the measure of simulation utility. Simulated SAR images were generated from enhanced versions of existing DMA products, Level 1 and Level 2 DFAD, and from high-resolution data bases, Level Y and Level X. These simulations, plus recorded SAR images, were used by OSOs in a B-1 simulator to locate a specified aimpoint. Accuracy of crosshair placement and operator confidence in placement, and ratings of acceptability for mission rehearsal for each simulation, were compared to performance and ratings for the actual SAR.

Research Methods

Overview

Simulated SAR images were generated from four data bases for 15 scenes. Actual B-1B SAR images were also obtained for these scenes. The simulated and actual SAR were recorded for presentation in the OSO station of the B-1 Engineering Research Simulator. SAR-experienced OSOs first studied Fixpoint Graphic cards for the 15 scenes and then used the radar screen and track handle in the ERS to place the crosshairs on the target. Placement accuracy and operator confidence for the different data base levels were compared to performance using the actual SAR. The OSOs were then debriefed to determine what radar features were contained in each image and the overall acceptability of the image for mission rehearsal.

Materials

Data Bases. For each of 15 fixpoints in the Strategic Training Range Complex, four data bases were obtained from DMA or created at ASD/ENETV. The data bases were: Level 1 (100m) enhanced, Level 2 (30m) enhanced, Level Y (15m), and Level X (10m). In three of the scenes, Level Y contained block areal features which were aggregrations of reflectors that were individually portrayed in Level X; these areal features were enhanced in Level Y as well as in Levels 1 and 2. Also, if the selected aimpoint was not present, it was inserted into all data bases.

The 15 Level Y and 11 of the 15 Level 2 data bases were created at ASD/ENETV. This was accomplished by filtering the DMA Level X data to the appropriate level of detail. Some features were retained regardless of size because of their reflectivities. All objects with certain Feature Identification Descriptors (FIDs) (e.g., power pylons) were also retained. The conventions used correspond to DMA procedures for capturing features in Level 2 and are summarized in Table 6.

Table 6. Exceptions to the Data Base Capture Criteria Used by ASD/ENETV in Generating Level 2 and Level Y Data from Level X.

1. All features with a Surface Material Code (SMC) of 1 (metal) or 2 (part-metal) were retained.

2. Level X features coded with Feature Identification Descriptor (FID) 917 (cultivated field) were changed to FID 902 (normal soil) when creating Level 2 data bases.

3. Level 2 FIDs 250 and 251 (roads) were included regardless of

4. Level Y FIDs 240 - 255 (roads) were included regardless of size.

5. The following FIDs were retained in Levels 2 and Y regardless of size:

230 - 239	Road Interchanges
260 - 267	Bridges
270 - 277	Bridge Superstructures
801 - 807	Tanks
820 - 824	Silos
915	Islands

6. All FID 927s (fences) were retained in Level Y regardless of length, while only fences 150m or longer were retained in Level 2.

A synthetic breakup program developed at ASD/ENETV was applied to areal features in Data Base Levels 1, 2, and Y. This program allows insertion of roads and buildings as specified by the user. Parameters within the breakup program included: road pattern (i.e., length, width, and orientation); building density; and building length, width, and orientation. Appropriate parameter values were inserted manually based on examination of aerial photographs of each area. This process maintained generic accuracy within the enhanced area but did not provide strict ground truth. Figures 9, 10, and 11 are data base plots for Greybull, Wyoming at Level 1 enhanced, Level 2 enhanced, and Level Y (no enhancements), respectively. When compared with Level 1 and Level 2 without enhancements (Figures 1 and 2), it is apparent that the enhancement process has primarily added secondary LOCs (residential streets) and small Structures (houses).

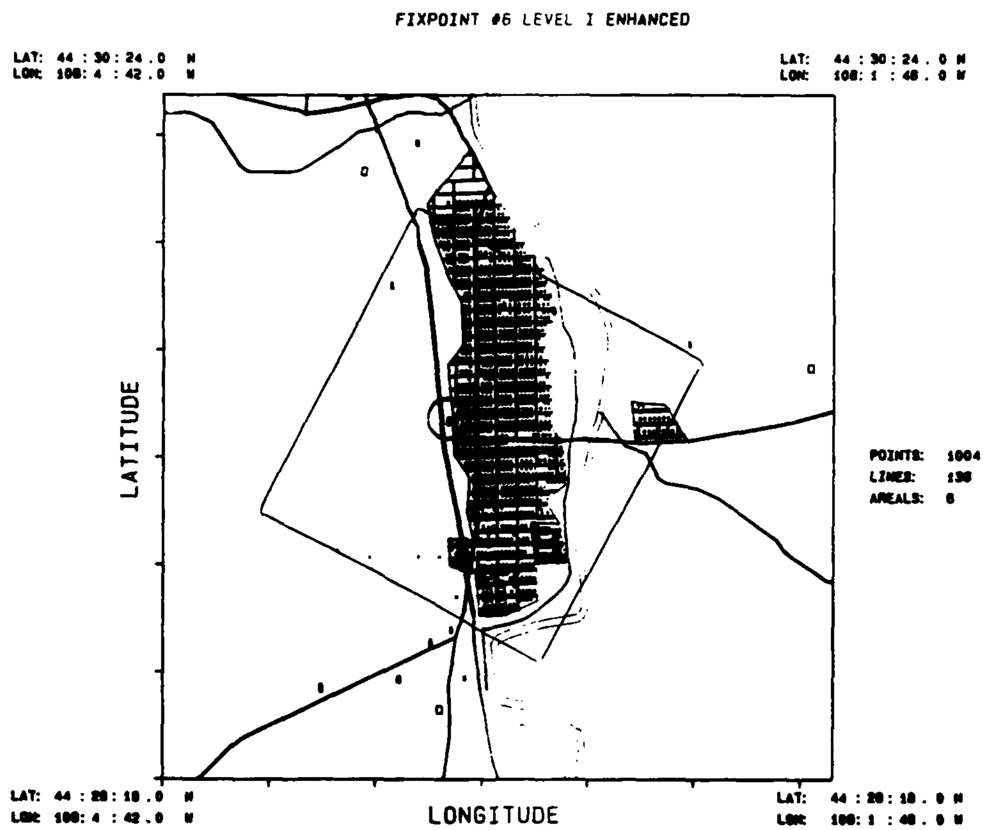

Figure 9. Plot of Digital Feature Analysis Data for Greybull, Wyoming, at Level 1 as Enhanced for the High-Resolution Optimization Study.

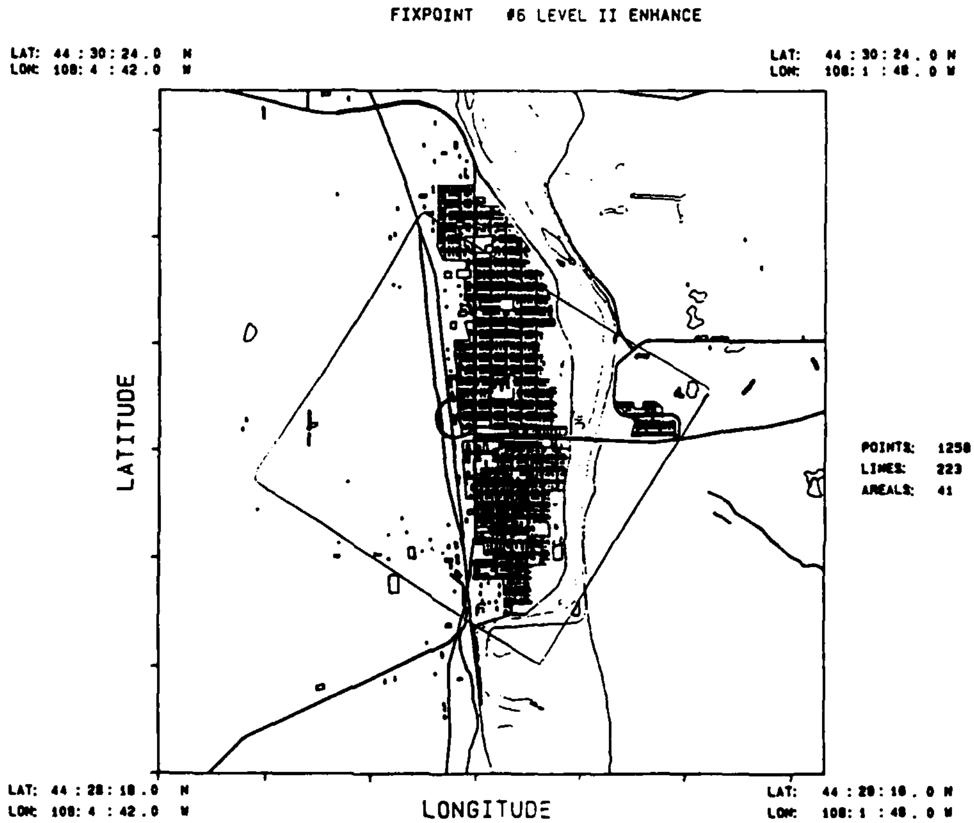

Figure 10. Plot of Digital Feature Analysis Data for Greybull, Wyoming, at Level 2 as Enhanced for the High-Resolution Optimization Study .

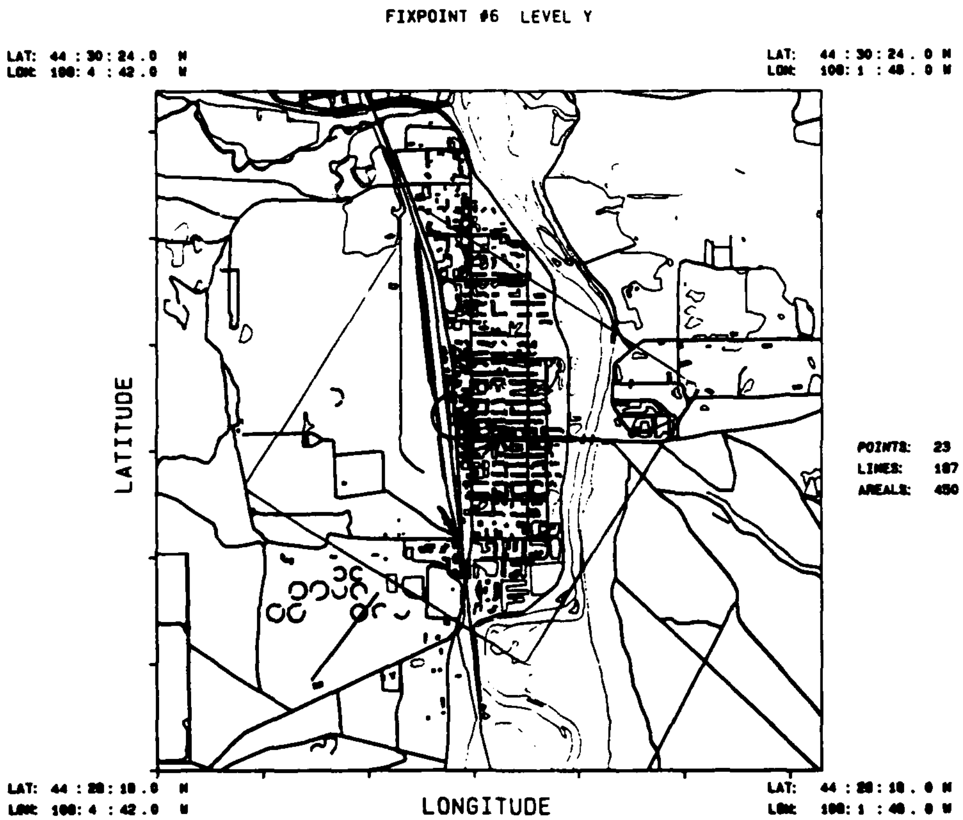

Figure 11. Plot of Digital Feature Analysis Data for Greybull, Wyoming, at Level Y Used in the High-Resolution Optimization Study.

Transformation and Image Generation. Simulated SAR images were generated on a General Electric DRLMS located at ASD/ENETV. This DRLMS was developed to simulate B-52/KC-135 real beam radars and has been modified to process high-resolution data. The transformation reflectivity and radar gains were optimized for each scene to obtain maximum correlation with the actual SAR and the most accurate portrayal of the different data bases. The simulated SAR images were generated for a 0.625nm x 0.625nm patch and formatted to match the actual SAR.

SAR Imagery. SAR images for the 15 scenes were obtained from a test flight of a BAC-111 aircraft owned by Westinghouse and used for development of the B-1B radar. Aircraft altitude was approximately 10,000' and range was 7 to 10nm, resulting in depression angles of 8 to 14 degrees.

Simulator and Study Software. The B-1B Engineering Research Simulator was developed by Scientific Applications International Corporation (SAIC) under contract with the Armstrong Aerospace Medical Research Laboratory and was located at the 338th Combat Crew Training Squadron, Dyess AFB, Texas. Only the radar screen and track handle of the OSO station were used for the Optimization study. To appear on the radar screen, simulated radar images are created off-line, stored on video disk, and called up as appropriate. Since this system allows storage of any image on video disk, the actual SAR images could also be presented in the simulator. Using a predetermined sequence, the study software called up the appropriate images for each subject, controlled the timing of events, and recorded the subject's placement accuracy and confidence.

Experimental Design

Stimulus images consisted of SAR simulations generated from four data bases, plus actual SAR, for 15 scenes. The scenes were blocked into three groups, Urban, Small Group, and Isolated, based on the number of features surrounding the aimpoint. Each subject saw only one level of each scene. The combination of scene and image level was balanced so that each subject saw three scenes from each of the four levels of data bases and three actual SAR scenes. Stimulus presentation order was randomized for each subject. Twenty-five subjects were required for complete balance. Since there were only five observations per level per scene, data were analyzed by scene group (Urban, Small Group, Isolated) rather than by individual scene. The dependent variables were: (a) deviation of the subject's crosshair placement from an Optimal Aimpoint previously determined by a Strategic Air Command (SAC) subject-matter expert, and (b) operator confidence rating.

Subjects

Subjects were 25 SAR-experienced B-1B OSOs and instructors. Median experience was 220 B-1B hours. All subjects had over 1,000 total flight hours.

Procedures

Briefing. Each subject was tested individually. The purpose of the experiment and the type of data to be collected were described (see Appendix A). The OSO was then given 10 minutes to study the Fixpoint Graphic cards of the 15 scenes in the study, plus two scenes for warm-up.

Warm-Up Trials. All OSOs received two warm-up trials using the same images; performance and confidence data were collected but not retained. After both warm-up trials, there was a pause for the experimenter to answer any questions.

Data Collection. After the warm-up trials, data were collected in three sets of five trials, with a break between sets. The OSO's task was to locate the designated aimpoint as accurately as possible on the radar screen within 60 seconds. Before each trial, the OSO was given 30 seconds to study the Fixpoint Graphic. At the end of the study interval, the screen alphanumerics were illuminated and a tone sounded, indicating that the OSO should request a radar map. When the map was completely drawn, the crosshairs appeared in the center of the screen and a response time clock started. The OSO moved the crosshairs by depressing the track handle trigger and pushing a thumb control. When satisfied with the placement, the OSO depressed a button on the track handle which blanked the screen and the trial ended. If a target was not selected within 60 seconds, the screen blanked automatically, erasing the image. A warning tone sounded 15 seconds before the screen blanked. After the target was designated, the OSO stated his confidence in the placement on a 7-point scale ranging from "1--Complete Guess" to "7--Very High Confidence." The experimenter entered this rating at a terminal and started the study period for the next trial.

Debriefing. After performance data were collected for all 15 stimuli, subjects were shown photographs of the images they had seen, along with the appropriate Fixpoint Graphic. The OSO then examined each photograph and completed a questionnaire rating the visibility of different types of features and the acceptability of the image for "Procedures Training" and for "Mission Rehearsal" (see Appendix B).

Results and Discussion

Placement Accuracy

Crosshair placement accuracy was defined as the radial miss distance between the subject's placement of the crosshairs and the ideal crosshair placement within each image. The ideal crosshair position was defined using two separate techniques. The first technique, previously described under Experimental Design, used the Optimal Aimpoint designated by the SAC subject-matter expert. The second technique defined the ideal crosshair position for a given scene as the mean of the crosshair placements designated by subjects when viewing the actual SAR image of that scene.

To make the variances more uniform across conditions and to reduce the relative importance of a few very poor crosshair placements, a logarithmic transformation was applied to the miss distances. This transformation can be expressed as:

$$X' = \mathrm{Log}_2 \ (X + 1)$$

$$Y' = \mathrm{Log}_2 \ (Y + 1)$$

$$d = (X'^2 + Y'^2)^{1/2}$$

where X is the untransformed miss distance on the horizontal axis, Y is the untransformed miss distance on the vertical axis, X' and Y' are the transformed miss distances on each axis, and d is the composite miss distance used in the analyses.

Figure 12 shows the mean of the transformed differences between the subjects' crosshair placements and the Optimal Aimpoint. The crosshair placement errors have been scaled such that the mean miss distance for Isolated fixpoint SAR images equals 1.0. The mean placement accuracy for each of the other combinations of scene type and data base was then scaled relative to this value so that the ratio property of all values was retained. Therefore, it is mathematically correct to describe the mean transformed error for Level 1 enhanced Urban fixpoints as being twice as large as the mean transformed error for Level 1 enhanced Isolated points.

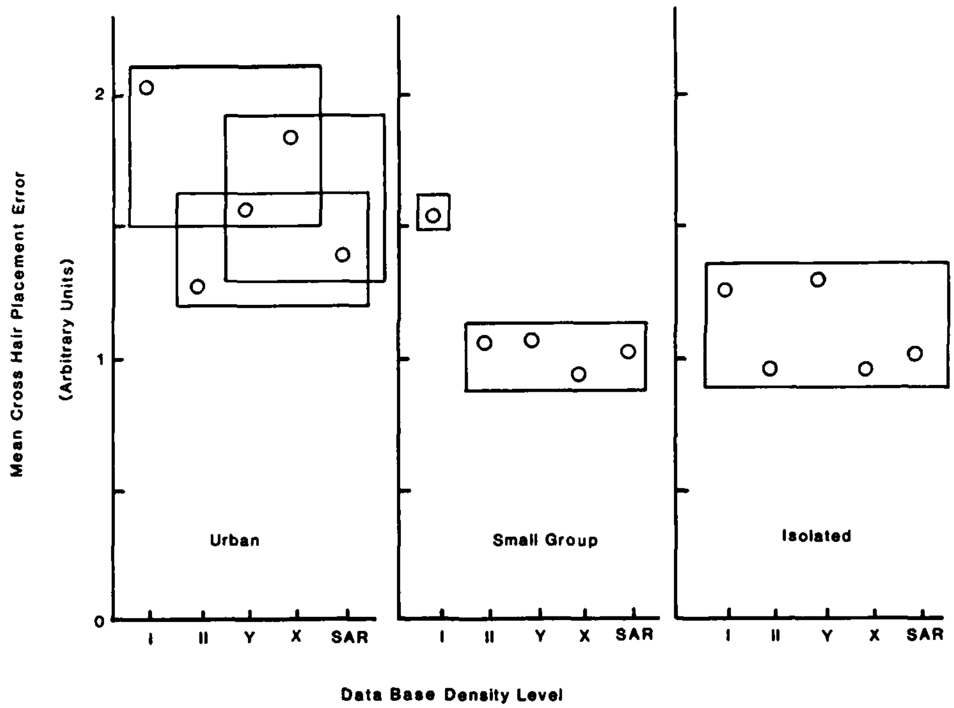

Figure 12. Mean Log Miss Distance from the Optimal Aimpoint for Each Group and Data Base Level in the High-Resolution Optimization Study. The vertical axis on this figure is scaled in arbitrary units. Means within a given rectangle were not significantly different from each other ($p < .05$).

Overall crosshair placement was less accurate for Urban fixpoints, and Level 1 enhanced images produced less accurate placements than did other data base levels ($p < .05$). The miss distances were statistically analyzed using a partially balanced incomplete block design (Kempthorne, 1979) analysis of variance. For the miss distances shown in Figure 12, this analysis shows that data base density level significantly affected the accuracy of crosshair placement for both Urban [$F(4, 90) = 3.49$, $p = .011$] and Small Group fixpoints

[$F(4, 91) = 3.10$, $p = .019$]. No effect was found for data base with Isolated points ($p > .05$). The significant main effects were further analyzed using Fisher's Protected Least Significant Difference test (Cohen and Cohen, 1983). The results of this post hoc analysis are summarized through the use of rectangles in Figure 12. For each type of fixpoint, the means enclosed within a given rectangle were not significantly different from other means enclosed within the same rectangle ($p > .05$); means enclosed by different rectangles were significantly different from each other ($p < .05$).

A similar analysis using the miss distances computed from the mean SAR crosshair placements showed that the data base density level significantly affected crosshair placement only for the Small Group fixpoints [$F(3, 67) = 7.57$, $p < .0005$]. No effects were found for data base on either Urban or Isolated points ($p > .20$). Post hoc analysis of Small Groups data showed that placements were significantly less accurate for Level 1 enhanced than for Level 2 enhanced, Level Y, Level X, and SAR.

The following conclusions can be drawn from these analyses of the crosshair placement data:

1. Location of aimpoints within Urban areas is a more difficult task than location of Isolated aimpoints or aimpoints within Small Groups of reflectors.

2. Data base density level did not affect placement accuracy for Isolated aimpoints. The isolated aimpoints included objects such as the end of a bridge, or a radio tower along the side of a road. Since these objects were the most salient features within the scene, the presence or absence of other smaller features did not affect performance.

3. Data base level significantly affected placement accuracy for Urban and Small Group fixpoints. In these cases, the small features present in the Level 2 enhanced, Level Y, and Level X data bases served as contextual cues to aid in locating the aimpoint whereas their absence from Level 1 enhanced images degraded performance.

Confidence Ratings

The confidence ratings were analyzed using an incomplete blocks model analysis of variance. There was a significant effect due to data base level for the Urban scenes [$F(4, 82) = 9.18$, $p < .0005$], the Small Group scenes [$F(4, 90) = 8.59$, $p < .0005$], and the Isolated scenes [$F(4,90) = 4.09$, $p < .004$). Confidence was lowest for Level 1 enhanced imagery for all groups; there were no significant differences in confidence among the Level 2 enhanced, Level Y, and Level X. There was a significant negative correlation between confidence scores and miss distance ($r^2 = .234$, $p < .05$). The correlation between confidence and miss distance indicates that the OSOs were accurate predictors of their own performance; i.e., lower confidence was associated with less accurate placements. This validates the use of operator confidence as a measure of simulation utility for this task. Confidence was not correlated with B-1B flight hours ($r^2 = .012$) nor were flight hours correlated with miss distance ($r^2 = .006$). The lack of correlation between B-1B flight hours and confidence or miss distance indicates that effects are due to differences among the experimental conditions and not to differences among subjects.

Debriefing Questionnaires

The data obtained from the Debriefing Questionnaires (Appendix B) were analyzed to determine the influence of data base level on the subjects' responses. First, the subjects' responses were recoded as either Low (0, 1, or 2) or High (3 or 4). Then, multidimensional contingency tables were formed by tabulating the subjects' responses for each debriefing question for each scene type and data base density level. Finally, a log linear analysis was used to determine if these multidimensional tables could be reduced to simpler two- or three-way contingency tables without significant loss of information. This analysis revealed that two-way tables were adequate to represent the data.

The two-way tables indicated that the data base level significantly affected subjects' ratings of major road visibility, small feature visibility, and acceptability for mission rehearsal. The relationships between data base and subjects' responses are shown in Tables 7 through 9.

Table 7. Number and percent of questionnaire responses for the item, "Are major roads visible?" for each data base density level.

		"Are Major Roads Visible?"		
		NOT VISIBLE	CLEARLY VISIBLE	ROW TOTAL
Data Base Density Level	1	47 65.3%	25 34.7%	72 19.7%
	2	32 43.2%	42 56.8%	74 20.3%
	Y	23 31.5%	50 68.5%	73 20.0%
	X	27 36.5%	47 63.5%	74 20.3%
	SAR	15 20.8%	57 79.2%	72 19.7%
Column Totals		114 39.5%	221 60.5%	365 100%

Table 8. Number and percent of questionnaire responses for the item, "Are small features visible?" for each data base density level.

		"Are Small Features Visible?"		
		NOT VISIBLE	CLEARLY VISIBLE	ROW TOTAL
Data Base Density Level	1	66 90.4%	7 9.6%	73 19.8%
	2	53 72.6%	20 27.4%	73 19.8%
	Y	43 58.1%	31 41.9%	74 20.1%
	X	40 54.1%	34 45.9%	74 20.1%
	SAR	29 39.2%	45 60.8%	74 20.1%
Column Totals		231 62.8%	137 37.2%	368 100%

Table 9. Number and percent of questionnaire responses for the item, "Is this image acceptable for mission rehearsal?" for each data base density level.

		"Is This Image Acceptable for Mission Rehearsal?"		
		NOT ACCEPTABLE	ACCEPTABLE	ROW TOTAL
Data Base Density Level	1	62 83.8%	12 16.2%	74 19.9%
	2	45 60.0%	30 40.0%	75 20.2%
	Y	40 54.1%	34 45.9%	74 19.9%
	X	45 60.8%	29 39.2%	74 19.9%
	SAR	25 33.8%	49 66.2%	74 19.9%
Column Totals		217 58.5%	154 41.5%	371 100%

Post hoc analyses of these tables showed the following ordering ($\underline{p} < .05$) between subjects' responses for the different levels of data base:

- Visibility of major roads
  Level 1 enhanced < Level 2 enhanced = Level Y = Level X < SAR

- Visibility of small features
  Level 1 enhanced < Level 2 enhanced < Level Y = Level X < SAR

- Acceptability for mission rehearsal
  Level 1 enhanced < Level 2 enhanced = Level Y = Level X < SAR

Analysis of the Confidence and Debriefing data support the conclusions drawn from crosshair placement accuracies. OSOs had less confidence in placements using SAR simulations generated from Level 1 enhanced data than for Level 2 enhanced, Level Y, or Level X. Likewise, the subjects reported seeing fewer features in Level 1 enhanced and rated it significantly less acceptable than the other Levels for mission rehearsal. There were no significant differences in acceptability for mission rehearsal among Level 2 enhanced, Level Y, and Level X; however, it should be noted that all three levels were rated as less acceptable than actual SAR images.

Comparison with Density Requirements Study

In the Density Requirements study, Level 2 was rated by OSOs as acceptable for simulating SAR on only 10% of the trials while Level Y was rated acceptable on 82% of trials (see Table 3). In the present study, no significant differences were found in task performance, confidence in placement accuracy, or rated acceptability for mission rehearsal between Level 2 enhanced, Level Y, and Level X. There are, however, pronounced differences between the simulated SAR images used in the two studies.

For the Density Requirements study, simulations were produced without breakup and with minimal texturing. This meant that reflectors such as houses, small buildings, or minor roads were not depicted in Level 2 imagery. The smaller capture criteria for Level Y and Level X allowed these features to be imaged individually so that these simulations appeared more like SAR than the simulations based on Level 2. In the present study, Level 1 enhanced and Level 2 enhanced contained additional information on roads and buildings obtained from aerial photographs and not from DMA data base products. The synthetic breakup and texturing added to the Level 2 enhanced images appear to have been sufficient to improve realism and allow the OSOs to perform the task. It should be noted that the realism in Level Y and Level X is obtained from ground truth while the realism in the Level 2 enhanced images is partially generic. The information in Level 1 DFAD, however, is so sparse that adding enhancements did not produce acceptable simulations.

Conclusions

The following conclusions can be drawn from the Crosshair Placement Accuracy, Confidence, and Debriefing data for the High-Resolution Optimization study:

1. A satisfactory simulation of SAR was not created from Level 1 DFAD. The addition of synthetic breakup did not add sufficient information to Level 1 to support adequate task performance.

2. No significant differences in task performance, operator confidence, or acceptability for mission rehearsal were found among the Level 2 enhanced, Level Y, and Level X images.

3. For the aimpoints used in this study, the highly detailed ground truth information contained in Level X did not produce better task performance, operator confidence, or acceptability for mission rehearsal than did the less detailed ground truth in the Level 2 enhanced data base.

4. Neither training nor transfer of training was addressed in this study since task performance was assessed using experienced SAR operators as subjects.

V. CONCLUSIONS

The data for these three studies were collected from highly experienced SAR operators and reflect expert evaluation and task performance. No data were collected from novices training to be SAR operators, nor was transfer of training from simulation to actual SAR assessed. Constraints of time, personnel, and ongoing training schedules prevented the use of 'aining or transfer-of-training designs. The studies conducted were based on the hypothesis that simulations which are acceptable to SAR experts will contain the task-critical elements of SAR imagery required to support training of novice SAR operators. It is possible that there are training tasks for which high-resolution ground truth data bases are required; however, no attempt was made to identify such tasks.

The previously cited engineering analysis conducted by TASC (1985) concluded that acceptable SAR simulations would be supported by Level X (10m) DFAD. This conclusion was supported by the ratings from SAR subject-matter experts in the Density Requirements study. Further, these data show that the capture criterion could be relaxed from 10m to 15m without affecting the acceptability of the simulations. However, the depiction of high density areas as single areal features in Level 2 did not produce acceptable simulation fidelity. In contrast, the SAR Radar Scope Interpretation Cue Analysis showed that individual reflectors within high density areas are rarely used as cues and that ground truth information about these features may not be task-critical. Although such an area must have the appearance of the appropriate ground returns and not uniform brightness, the reflectors may be depicted generically and still maintain acceptable simulation fidelity without affecting task performance. Other features such as major roads, rivers, and other lines of communication are task-critical and must be depicted accurately. The results of the High-Resolution Optimization study confirmed this prediction. The information about task-critical features contained in Level 1 was insufficient to support OSO task performance even though the data were enhanced. Level 2, however, contains sufficient information about task critical features to support OSO task performance when enhanced with generic information about high density areas. The increases in feature density provided by Level Y or Level X are not task-critical.

Based on the data from the present investigations, the following conclusions may be drawn:

1. Line features such as roads and rivers as depicted in DMA Level 2 DFAD are task-critical in simulating SAR.

2. SAR simulations must contain the appearance of SAR throughout the scene. Depiction of clusters of reflectors as an area of uniform brightness is not acceptable.

3. Ground truth information about features smaller than those depicted in Level 2 is not task-critical. Generic portrayal of high feature density areas will provide acceptable SAR simulation.

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APPENDIX A--Briefing for High-Resolution Optimization Study

1. The 96th BMW is cooperating with Aeronautical Systems Division and the Air Force Human Resources Laboratory in a study on simulation of Synthetic Aperture Radar. The results of this study will help SAC to specify the data base requirements for SAR simulation in the B-1 Weapon System Trainer. Your help as an expert on SAR imagery interpretation is requested. In this study, you will use the ERS to view a number of actual and simulated SAR images. You are to examine each image and to then designate the aimpoint as quickly and accurately as possible.

2. For this study, your only task is to study a fixpoint card, request a single radar map, and then to designate the aimpoint. The scenes are independent events and not parts of a mission. Only the radar scope and track handle will be active; all other systems will be illuminated but not functional. Alphanumeric data on the radar scope are not the actual SAR image parameters and should be ignored.

3. Before entering the ERS you will be given 10 minutes to study 17 Fixpoint Graphic cards. Once inside the ERS, the first two trials will be for practice and the remaining 15 will constitute the study. Before every trial, you will have 30 seconds to review the fixpoint card. Then, the screen alphanumerics will be illuminated and a tone will sound indicating that you should request a map. Place the crosshairs onto the specified aimpoint as accurately as possible. When you are satisfied with the placement, designate by pressing the button to request a second map. It is important that you designate as soon as you are satisfied with your placement since this stops a response time clock. If you do not designate an aimpoint within 60 seconds, the screen will blank and the next trial will start. After designating the aimpoint, please rate your confidence in placement accuracy using the following scale:

```
     1         2         3         4         5         6         7

     !---------!---------!---------!---------!---------!---------!
Complete                                                    Very High
 Guess                                                      Confidence
```

The experimenter will enter your rating and start the 30-second study period for the next trial. The experiment will pause after the two practice trials for you to ask any questions. The remaining trials will be presented in groups of five.

4. After data collection, we will ask you to evaluate the imagery.

5. The data you provide will be of great value to Aeronautical Systems Division and the Defense Mapping Agency in developing the data base which will support the B-1B Weapon System Trainer. Thank you for your help.

APPENDIX B--Debriefing Questionnaire for High-Resolution Optimization Study

IMAGE # ________ NAME ____________________ # ____________ DATE __________

Compare this image to what you can see in the fixpoint graphic and to what you would expect to see on the B-1 SAR.

1. Is the fixpoint visible on the radar image?

```
              !---------!---------!---------!---------!
              0         1         2         3         4
          Not Visible                           Clearly Visible
```

2. Are major roads visible?

```
              !---------!---------!---------!---------!                N/A
              0         1         2         3         4
            No Roads           Some Roads          Most Roads
            Visible              Visible        Clearly Visible
```

How important are major roads in locating this aimpoint?

```
              !---------!---------!---------!---------!
              0         1         2         3         4
          Not Important                             Critical
```

3. Are large features such as rivers, airfields, or towns visible?

```
              !---------!---------!---------!---------!                N/A
              0         1         2         3         4
          No Large          Some Large           Most Large
     Features Visible    Features Visible    Features Visible
```

How important are large features in locating this aimpoint?

```
              !---------!---------!---------!---------!
              0         1         2         3         4
         Not Important                              Critical
```

4. Are small features such as houses, tanks, or towers visible?

```
              !---------!---------!---------!---------!                N/A
              0         1         2         3         4
          No Small          Some Small           Most Small
    Features Visible    Features Visible     Features Visible
```

How important are small features in locating this aimpoint?

```
              !---------!---------!---------!---------!
              0         1         2         3         4
         Not Important                              Critical
```

5. Would this image be acceptable as a simulator for:

```
Procedures Training    !---------!---------!---------!---------!
                       0         1         2         3         4
                  Unacceptable       Satisfactory     Fully Acceptable

Mission Rehearsal      !---------!---------!---------!---------!
                       0         1         2         3         4
                  Unacceptable       Satisfactory     Fully Acceptable
```


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